

## Outokumpu's Technologies for Efficient and Environmentally Sound Nickel Production

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### ABSTRACT

This paper deals with the nickel smelter and refinery concepts Outokumpu has applied at Harjavalta and several other plants. Also other process routes and modifications developed and tested by Outokumpu during the recent years are highlighted.

Outokumpu started nickel production in Harjavalta in 1959. Until 1995 the Flash Smelting – Peirce-Smith (PS) converting route was applied. High grade nickel matte from the converting step was further refined by means of leaching and electrowinning to produce cathode nickel. In 1995 the nickel production capacity was increased from 17 000 t/a to 52 000 t/a based on the Direct Outokumpu Nickel Smelting Process (DON).

In the DON process PS converting is eliminated and high grade nickel matte with low Fe-content is directly produced in the flash smelting furnace (FSF). Metal values from the smelting slag are recovered in the electric furnace (EF) as iron containing Ni-matte. The DON process can be operated with either two matte concept, where high grade FSF matte and EF matte are produced, or a single matte concept, where EF matte is recycled to the smelting furnace and thus only one type of high grade matte is obtained.

The additional refinery capacity at Harjavalta is based on hydrogen reduction producing nickel powder and briquettes. Leaching of two types of matte was resolved by setting up separate leaching circuits for each matte. Copper in matte is recovered as sulphide. Cobalt and minor impurities are removed from the nickel sulphate solution by solvent extraction and thereafter the solution is fed to the electrowinning and hydrogen reduction plant. In the process concepts operated and developed by Outokumpu, it is possible to deal with the issues often related to nickel production: MgO content, PGM's and cobalt recovery. Outokumpu Technology is able to provide process solutions to yield nickel and other valuable elements with high recovery from various types of concentrates in profitable and efficient methods considering also environmental and occupational aspects.



## INTRODUCTION

During recent years there has been a lot of discussion on new leaching technologies replacing pyrometallurgical routes. However, about 90% of the world's nickel production capacity is still based on pyrometallurgical processes. It is also important to note that there are six operating nickel flash smelters based on Outokumpu technology making more than 50% of nickel matte smelting production capacity. Refining of high grade nickel matte utilizes mainly hydrometallurgical methods. Also in this area Outokumpu has extensive experience. Outokumpu Technology owns the intellectual property rights of the whole process area.

## NICKEL RAW MATERIALS, PRODUCTION, CONSUMPTION AND TRENDS

The importance of nickel comes from its ability, when alloyed with other elements, to increase a metal's strength, toughness and corrosion resistance over a large temperature range. Nickel is essential to the iron and steel industry, in particular to stainless steel and nickel-containing alloys play a key role for aerospace, marine, electronics and construction applications.

### Raw Materials

Nickel in the earth can be found in two different types of mineralizations: Sulphidic and lateritic. The laterites can be further divided into two types: Limonites (<5%MgO and < 1.5%Ni) and saprolites (MgO up to 35%, Ni 2-3%). Besides with nickel the sulphidic ores contain copper and cobalt. Quite often sulphidic ores contain Platinum Group Metals (PGM's) in considerable amounts, which play an economically more important role compared to nickel. Impurity contents such as arsenic and magnesia may cause problems in processing. The variety of raw materials and products results in case tailored needs for process technology for specific type of raw material.

An essential difference between sulphidic and laterite raw materials is that sulphidic ores can be concentrated by flotation methods to increase nickel content thus decreasing the material quantity to be processed in the next phase. Concentration is not applicable to laterite ores but the entire material amount has to be processed.

### Production and Consumption

Nickel products can be divided into three groups: 1) Refined nickel (class I), 99% or more: Electrolytic nickel, pellets, briquettes, granules, rondelles and powders/flakes. 2) Charge nickel (class II), < 99%: Ferronickel, nickel oxide sinter and utility nickel. 3) Chemicals: Nickel oxides, sulphates, chlorides, carbonates, acetates, hydroxides etc.

Figure 1 shows that 70% of the world mine production in 2003 is provided between five countries: Russia, Australia, Canada, Indonesia and New Caledonia. The distribution of nickel refinery production is a little bit more diverse, however, major producing countries Russia, Australia and Canada are still the same. Japan, although possessing high demand, does not have natural resources.

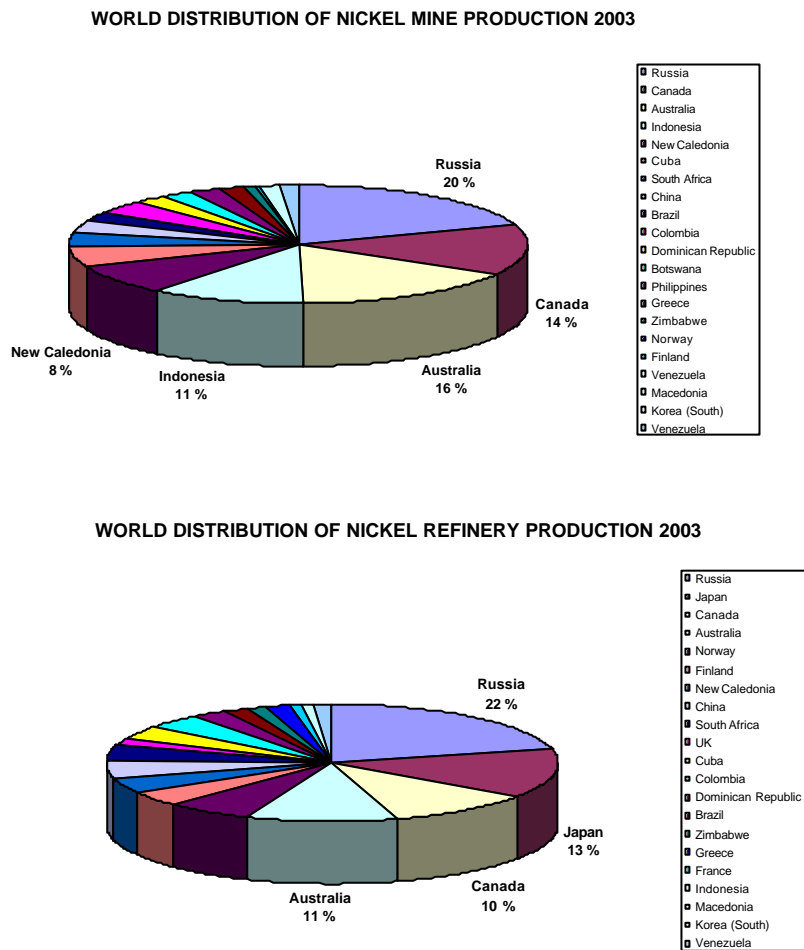


Figure 1 - World distribution of mine and refinery production in 2003

By the end of year 2004 industry stocks of nickel have been record low and LME nickel prices were trading well above long-run average levels. However, in medium term there appears to be many nickel projects and some possibility for oversupply in the years 2007-2009. Figure 2 illustrates the prospects for world production and demand balance /1/. The world consumption of nickel is currently more than 1.2 million tons per year, whereas production is broadly speaking in balance this year.

## NICKEL PRODUCTION AND CONSUMPTION 2003-2009

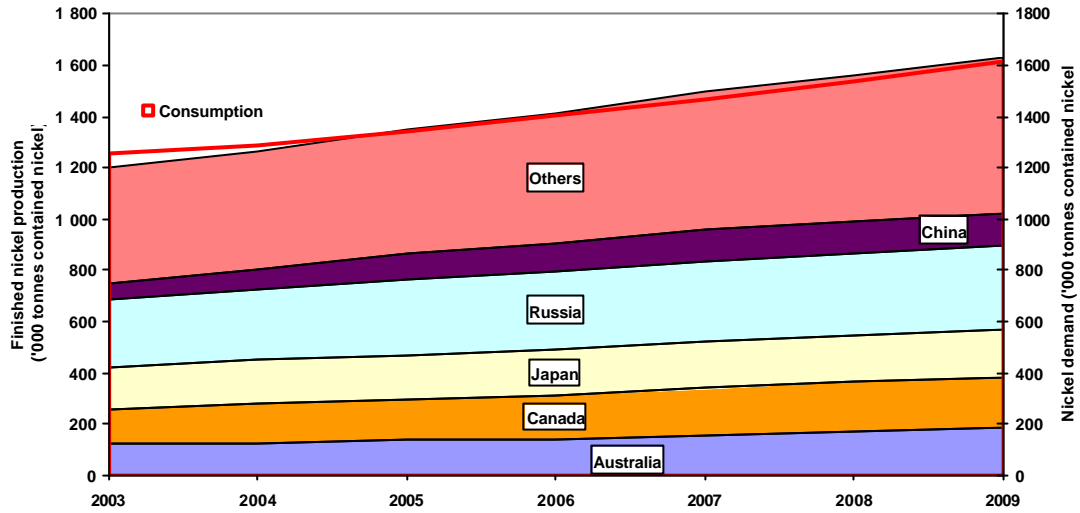


Figure 2 - Forecasted nickel production and demand ('000 tonnes contained Ni)

### Trends

Looking forward, world primary nickel production is expected to increase by more than 5 % per year. High prices have intensified exploration activity and thus new potential nickel projects around the world. The largest greenfield projects published include Voisey's Bay, Ravensthorpe and Goro.

It is interesting to note that although there has been much discussion concerning pressure acid leaching (PAL) replacing smelting technology, at the time being, only 10% of nickel production capacity is processed by leaching methods, as can be seen in Figure 3. Furthermore, even in the years to come pyrometallurgical technologies are expected to dominate production by more than 80% as a first processing step.

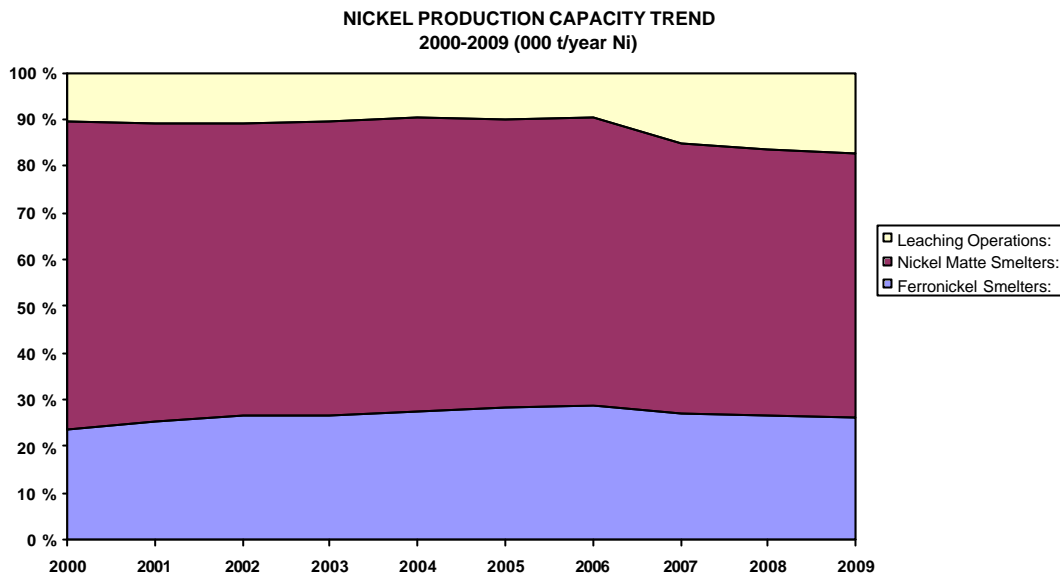


Figure 3 - Production capacity trend by first processing step

At the moment about 90% of nickel is processed by pyrometallurgical methods. A pyrometallurgical treatment of a sulphidic concentrate commonly includes roasting, smelting and converting. In flash smelting roasting and smelting are combined. Matte from the converting is further processed by hydrometallurgical methods. Today Outokumpu Flash Smelting and Direct Outokumpu Nickel (DON) process have become a dominant method for nickel smelting, as illustrated in Figure 4.

The original Outokumpu nickel smelter process was in operation in Harjavalta. Today it is still applied in two smelters, Selebi-Phikwe in Botswana and Norilsk in Russia. The Harjavalta smelter was modified in 1995 to correspond to the DON concept. The newest nickel flash smelter is Fortaleza in Brazil which's design was also based on the DON concept. The smelter started operation in 1998.

The Kalgoorlie (Australia) and Jinchuan (China) smelters use the Outokumpu flash smelting furnace, where the smelting and slag cleaning stages have been built together to form one integrated unit.

Outokumpu refinery technology with separate leaching of flash furnace matte and electric furnace matte is used in Harjavalta. Outokumpu refinery technology has been applied also for nickel carbonate raw material. The original leach/purification/electrowinning technology or part of it has been supplied to other producers.

### NICKEL MATTE SMELTER PRODUCTION 2003, %

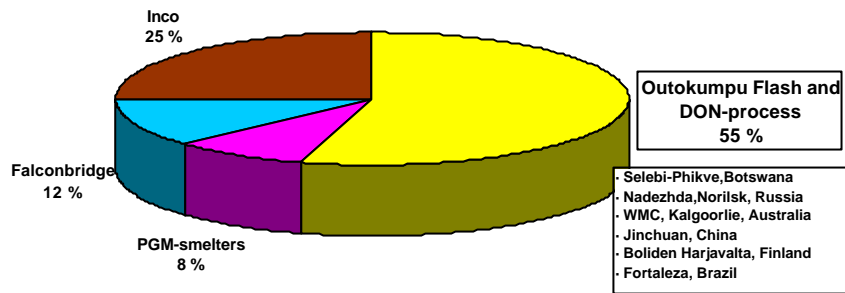


Figure 4 - Nickel matte smelter production

### HARJAVALTA PLANT

An incentive for Outokumpu's nickel production, started at Harjavalta Finland in 1959, was the discovery of the sulphide nickel ore body at Kotalahti. Although other options were available, it was natural that also for nickel concentrates the flash smelting method was applied. The process had been developed and adopted for making copper at Harjavalta in 1949. Today there are six nickel flash smelters operating in the world accounting for over 50 % of the existing smelter production capacity.

#### Smelter Developments

The original smelter flow sheet consisted of three main process steps: flash smelting, Peirce-Smith converting and electric furnace slag cleaning. The initial design capacity of the plant was 3000 t/a metallic nickel. Over the past decades, several modifications have taken place and the capacity has been increased. The biggest expansions were in 1972 and 1982. A major renovation was carried out in 1991.

The latest expansion of the plant was completed in 1995. This project aimed primarily at a higher cost efficiency but also the environmental issue was important. Besides the capacity increase up to 40000 tons of nickel/year, the entire process chain was modified. The smelter flow sheet was simplified when the newly developed DON-process (Direct Outokumpu Nickel smelting) was commissioned. The major change was that the converting step was eliminated. Instead of the high grade converter matte the

smelter now produces two types of matte: flash furnace (FSF) matte and electric furnace (EF) matte.

### **Smelter Flowsheet Today**

In the DON process as implemented at Harjavalta, dried concentrate is flash smelted directly in one step to high nickel low iron matte. Iron containing residue from the nickel refinery can be recycled to the smelting step.

The slag is laundered to the electric slag cleaning furnace where nickel is recovered as metallised matte containing iron. Melting temperature of the EF matte is adjusted by injecting nickel concentrate through a lance into the melt because of the low sulphur content of incoming slag. Nickel concentrate increases the sulphur content of matte and reduces its melting temperature. The slag from the EF is clean enough to be disposed off. The FSF and EF matte is granulated by water quenching of sprinkled melt. After grinding they are fed to the new hydrometallurgical processes for refining. The corresponding flowsheet is presented in Figure 5.

In 2003 New Boliden was incorporated and from the beginning of 2004 Harjavalta smelter has been part of that company.

### **Refinery Developments**

The Outokumpu base metal nickel refining technology is based on a sulphuric acid leaching of nickel /copper matte.

From year 1960 up to 1995 the Nickel refinery was designed to process low sulphur and low iron matte with minor value in PGM's typically 1-2-%. The process comprised a three stage atmospheric leaching, nickelic process for cobalt removal and nickel electrowinning. The sulphur and iron balances were generally maintained by recycling of residues to the nickel smelter. Due to the recycling PGM's and cobalt were lost into the slag. Late 1970's an autoclave leach process was introduced to make it possible to produce a PGM's containing copper sulphide residue with low nickel suitable for the adjacent copper smelter.

Year 1995 the process was converted and expanded to treat DON smelter FSF- and EF matte. The expansion included a separate leaching for high iron EF matte, solvent extraction for cobalt removal using Cyanex 272, hydrogen reduction for nickel and cobalt. The leaching efficiency was improved by introducing of new in-house designed leach reactors and improving autoclave mixing concepts. The new leach concepts using oxygen gas for oxidation have improved the tolerance of iron and arsenic.

Year 2000 OM Group, Inc. took over the nickel refinery operation. The refinery has since that gone through some modification by OMG but the refinery main process operates principally on the same basis.

## Refinery Flowsheet Today

The present operation comprises a two-stage counter current atmospheric leaching for FSF matte followed by pressure leaching. Oxygen gas is used for oxidation both in atmospheric and pressure leaching. Copper contained in the FSF matte is converted to secondary copper sulphides in the selective nickel pressure leaching utilizing the so-called metathesis reaction.

The EF matte leaching comprises an oxidizing atmospheric leach followed by a pressure leach where the copper, nickel and cobalt are leached and directed to the FSF leaching circuit. In the both circuits the matte is wet ground in a ball mill prior to the leaching.

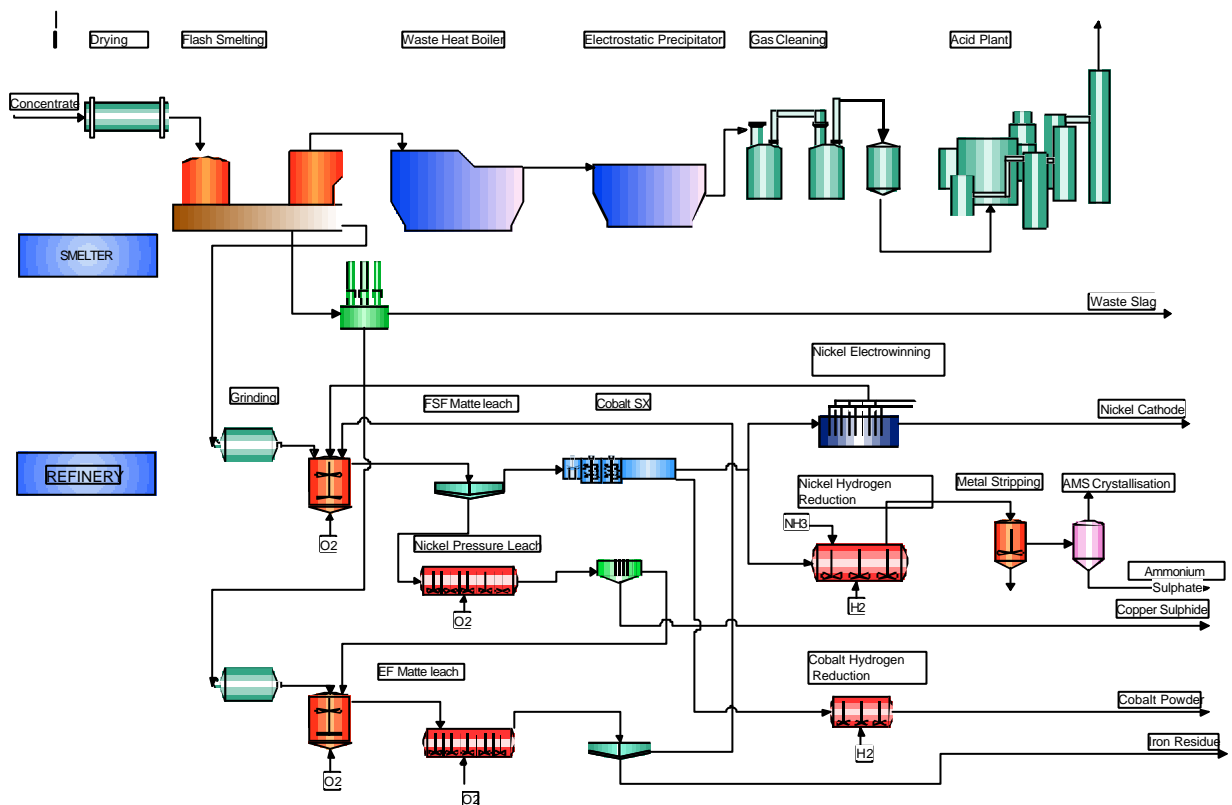


Figure 5 - Harjavalta nickel smelter and refinery flowsheet

The PGM's contained in the FSF matte reports to the leach residue or the secondary copper sulphides, which is led to the copper smelter. The precious metals report to copper anodes to be recovered from the anode slime at the copper refinery. From the atmospheric copper removal step (atmospheric leach 1) the copper free nickel-cobalt sulphate solution is directed to the cobalt solvent extraction circuit for solution purification.

The purified nickel sulphate solution is split between the nickel tank house, which produces nickel cathodes and the hydrogen reduction circuit to produce nickel briquettes. Ammonium sulphate is produced as a by-product contributing to maintaining the sulphur balance.

## **FEATURES OF OUTOKUMPU'S NICKEL PROCESSING TECHNOLOGIES**

The original nickel flash smelter - refinery concept may be satisfactory in many cases fulfilling the basic economic and environmental requirements. However, in competitive environment pressures to improve the plant performance will become ever stronger. Therefore, it is important to continuously look for new solutions and options to make smelting and refining technologies more effective. In the following the features of the DON smelting and related refining alternatives are discussed.

### **Raw Material Flexibility**

Nickel content in sulphidic nickel concentrates ranges normally from 5 to 12 % Ni. Concentrates from Western Australia have higher nickel concentrations typically 20 % and even higher, up to 25 %. Copper contents in these concentrates are very low, even below 0.1 % Cu while in other concentrates copper contents are relatively high, 1-6 %. An essential constituent in nickel concentrate is often cobalt, which is more valuable than nickel. Concentrations of cobalt vary in the range of 0,2-1 %. High recovery of cobalt is of great importance to the profitability of a smelter. In some cases nickel is produced as a by-product of other metals, the most notable example being the platinum group mines in southern Africa.

Analyses of some nickel concentrates, which are used by Outokumpu process or are tested and studied successfully for the DON process are shown Table 1.

Table 1 - Nickel concentrate analyses

Concentrates	% Ni	% Cu	% Fe	% Co	% S	% SiO <sub>2</sub>	% MgO	Ni/Cu	Fe/MgO	Fe/SiO <sub>2</sub>	g/t PGM	g/t Ag
Case A (Feasibility Study)	6.0	13.3	39.6	0.23	32.0	2.9	1.2	0.4	33.0	13.9		
Case B (Feasibility Study)	15.0	2.0	45.0	0.7	36.0	<0.5	<0.5	7.5	>90	>90		
Fortaleza (Oper. plant)	6.8	1.3	37.5	0.14	23.0	17.1	7.3	5.4	5.2	2.2	2.2	3.1
Case C (Feasibility Study)	13.9- 14.7	0.2- 0.4	28.5- 31.9	0.31- 0.39	28.5- 29.5	6.8-7.4	7.4-8.3	34-87	3.4-4.1	4.1-4.3		
Harjavalta (Oper. plant) *	11.5	1.5	24.5	0.36	21.8	23.2	5.3	7.9	4.6	1.1		
Case D (Feasibility Study)	9.6	4.6	35.9	0.46	28.6	9.2	7.1	2.1	5.1	3.9	14.8	13.0
Case E (Feasibility Study)	6.9	3.3	35.8	0.17	26.0	9.3	7.5	2.1	4.8	3.8		
*feed mixture												

The DON process allows optimization of the process conditions corresponding to the requirements of raw materials and products as well as other boundary conditions. For example in Fortaleza where nickel content in concentrate is relatively low, the oxidation is milder than at Harjavalta and thus the matte contains more iron. Conditions in the slag cleaning step can be adjusted independently from the flash smelting step. Also for sulphidation of EF matte several methods are available. Harjavalta utilizes concentrate injection while in Fortaleza liquid flash smelting matte is used.

The DON process can be operated with the EF matte circulation to the flash furnace. Thus only low iron FSF matte is produced which simplifies the refinery flowsheet because of decreased iron removal. This concept provides however that the feed materials don't contain elements in significant concentrations (e.g. cobalt) that would accumulate in circulation between the furnaces. On the other hand, PGM's containing concentrates may benefit this concept. Matte circulation has been successfully tested on a pilot scale. In addition industrial tests have been carried out at Fortaleza. Nowadays Fortaleza applies partial matte circulation.

In addition to the actual DON process Outokumpu has developed a process concept, where instead of nickel concentrate, nickel matte is used as a feed material to a

flash smelting furnace. This procedure, called continuous nickel converting, is applicable, for example, to old plants where existing electric furnaces can be used to upgrade the feed material suitable for flash smelting. By this concept several batch wise operated P-S converters can be replaced by one single flash smelting furnace.

### Refinery Options

Refinery technology is an essential part of Outokumpu's nickel processing technology. Below is listed the compositions of the matte for a variety of cases where the Outokumpu base metals refining technology has been applied.

Table 2 - Nickel matte analyses

Mattes/Analyses	Year	% Ni	% Cu	% Fe	% S
Outokumpu Harjavalta, (Full Scale)	1960	55-60	5-35	4-34	5-21
Case 1 (Full Scale)	1994-	42	34	0,4	22
Case 2 (Feasibility Study)	2000	41	32	3	22
Case 3 (Feasibility Study)	1995	60	14	5-31	5-21
Case 4 (Feasibility Study)	1996	43	30	5-31	5-21

The process can easily be adjusted to a variety of matte compositions with regard to copper, nickel, sulphur, cobalt and PGM's and taking into consideration local requirements for egg. with regard to sulphur balance. The process is a result of intense process development and proven in industrial scale. High-grade quality of main- and by-products giving maximised revenue.

At the moment the Harjavalta nickel plant is the only plant in the world, which is producing both electrolytic and hydrogen reduced nickel at the same plant. This means a variety of class I refined nickel products such as: nickel cathodes, sintered or non-sintered briquettes and nickel powder.

Solvent extraction has had a strong position within Outokumpu since 1970's when the first solvent extraction circuit was installed for molybdenum. Outokumpu Technology has developed the VSF technology (Vertical Smooth Flow). The VSF technology has been applied for several different projects for copper and cobalt/nickel separation.

The PGM's containing leach residue can be directed to the copper smelter or copper can be further pressure leached to dissolve copper and to concentrate the PGM's. Copper is recovered by electrowinning. The Outokumpu concept for leaching can be applied for many types of nickel containing materials using the combination of atmospheric leach/pressure leach together or separately.

Nickel carbonate or other nickel sources can be used as complementary raw material for the nickel circuit. Outokumpu know-how for leaching of basic nickel carbonate and electrowinning has been applied in Companhia Niquel Tocantins Brazil.

Late 1990's a new continuous process has been developed within Outokumpu for hydrogen reduction of nickel. The main objective has been to develop a cost effective nickel process for a product suitable specifically for the stainless steel industry.

The new process is called LTP-process (Low Temperature and Pressure). Due to the nature of the process the final nickel briquettes will contain 1 % Fe so the low cost nickel product is suitable for stainless steel industry which consumes >70% of the world nickel production. Compared to the conventional batch operating process the continuous LTP process has lower capital and operating cost.

### **Recovery of Precious Metals and Cobalt**

Nickel and copper recoveries in the conventional Flash Smelting - PS process are high despite of the high material circulation. On the other hand, the cobalt recovery has been relatively low. As there are no converters in the DON process the material circulation between process units is minimized. This has a very positive effect on the cobalt recovery. Also the recoveries of nickel and copper and PGM's can be maintained at high level.

Elimination of converting is particularly important for cobalt recovery as can be seen in Figure 6. In the refinery cobalt is stripped into a cobalt sulphate solution, which can be further processed to different cobalt products. The nickel free raffinate can be further refined to metallic cobalt by hydrogen reduction or electrowinning. While the cobalt recovery in the DON smelter has considerably improved the significance of the cobalt in the nickel refining has been increased.

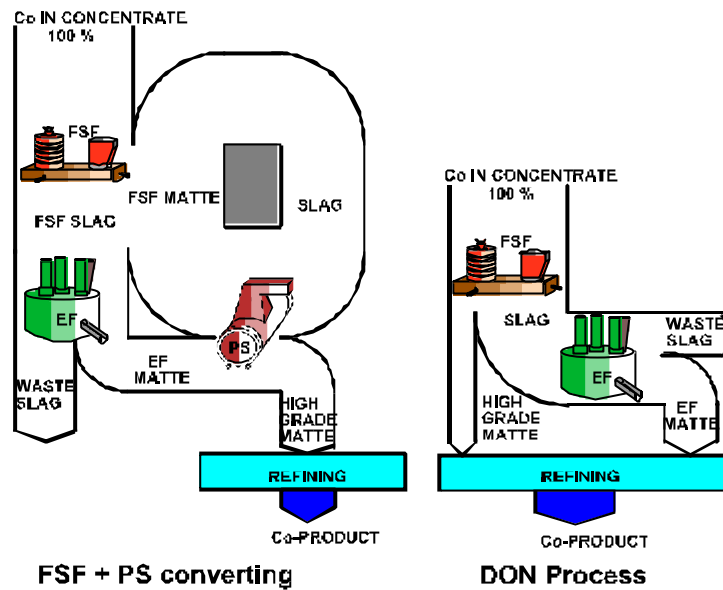


Figure 6 - Cobalt distribution in conventional Flash Smelting - PS process and in the DON process

In the DON smelter PGM's are effectively collected directly into the high grade matte formed in the flash smelting furnace, and the amount of PGM's going into slag cleaning furnace is almost of nil. In the refinery copper contained in the FSF matte is converted to secondary copper sulphide carrying the PGM's effectively. The PGM's containing leach residue can be directed to the copper smelter or copper can be further pressure leached to dissolve copper and to concentrate the PGM's. Copper is then recovered by electrowinning. PGM's contents can be further concentrated by polish leaching steps.

## **Facing the MgO Problem**

As shown in Table 1 nickel concentrates can contain considerable amounts of magnesium oxide. Therefore, MgO -content in the nickel smelting slag typically varies in the range 5-10 % being a basic constituent in the slag system.

Magnesium oxide influences strongly on the characteristics of the slag. When magnesia concentration of the slag increases beyond a few weight per cent, the melting behavior is modified significantly resulting in higher melting temperature and viscosity.

Quite recently, thanks to the advanced thermodynamic calculation methods and data bases, more and more information about these kind of complex slag systems has been generated.

Operating windows of the conventional nickel FSF and the DON FSF are presented in Figure 7. This diagram demonstrates that with the same Fe/MgO ratio in concentrate the operating temperature in the DON process can be kept lower than in the conventional FSF. This is because in the DON FSF more iron is oxidized thus diluting MgO concentration in the slag phase and increasing Fe/MgO ratio of the slag.

Iron residue from the nickel refinery can be recirculated to the flash smelting furnace. The iron residue has a favorable effect on slag composition diluting the MgO content and thus reducing operating temperatures. This also provides environmental benefit as the residue is converted into an innocuous slag. In some cases it may be more beneficial to discard the leaching residue being outlet for some impurities such as arsenic.

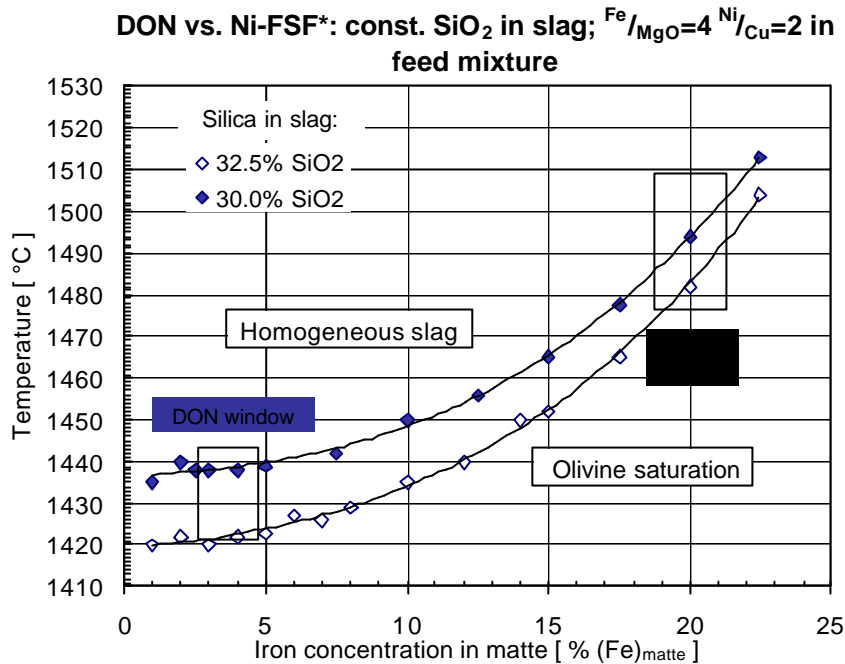


Figure 7 - Slag liquidus temperature as a function of iron content of matte in conventional FSF vs. DON FSF

### Investment and Operating Costs

Compared to the conventional nickel smelting, the new DON process needs a lower number of smelting vessels resulting in considerable economic and environmental benefits. Savings are attained in smelting section because converters, converter aisles with cranes, ladles and other equipment are not needed.

The batch operation of the PS converters generates large volumes of gas followed by periods with no gas at all. All gas handling facilities, but especially the acid plant, must be designed to cope with peak gas generation. In the DON process continuous gas flow with low volume and high SO<sub>2</sub> concentration means lower investment costs especially in the gas cleaning section, but also in the other areas of the sulphuric acid plant.

Furthermore oxygen plant required by the DON process is smaller in capacity than in the conventional method, which reduces the capital costs for the favor of the DON process.

Elimination of the converting section reduces manpower requirements. Furthermore, it decreases electricity consumption but on the other hand more electric energy is needed in the DON process because of increased reduction work in the slag

cleaning furnace. However, the net cost is lower in the DON process. The coke consumption depends on the reduction work in the slag cleaning furnace. In the DON process more reduction is needed than in the conventional process resulting in higher costs. Maintenance and fuel costs are naturally lower in the DON process resulting from the fewer process steps.

We have estimated capital and operating costs of two nickel smelters one applying the conventional Flash Smelting & PS Converting Technology the other using the DON process concept. Both smelters produce nickel matte with the annual capacity of 70 000 t/a nickel. According to our cost comparison the overall saving in capital costs when selecting the DON process is about 15 %. Reduction in operating costs is of the same order of magnitude.

### **Environment and Occupational Hygiene**

One main advantage of the DON process is the decreased treatment cost of sulphur dioxide gases. The process produces only one continuous, concentrated gas stream when the fluctuating converter gas flow is eliminated.

For example, the sulphur balance of the Harjavalta nickel smelter process indicates that the sulphur recovery into saleable products and slag is 99.2 %. The changes in the smelting process and technology and installation of the new sulphuric acid plant have made it possible to meet the new standards.

Relating to the specific SO<sub>2</sub> emissions (kg SO<sub>2</sub>/ t metal) of nickel smelters, there are wide variations between the smelters. In some countries a sulphur fixation of 90 % or even less is still sufficient. Some smelters still operate with very poor sulphur capture or even without any sulphur fixation.

Pressure to improve capture tends to come from local authorities. They can often impose standards that are higher than national limits, because of pressure from local residents. One can expect that the sulphur capture higher than 99 % will become more and more the standard. Thus many plants will need investments to improve their efficiency of sulphur collection. In nickel smelting DON is the answer for these requirements.

Batch operation with ladle transportation of molten materials is a source of fugitive gas and dust emissions. The DON process is almost continuous and no ladle transportation is needed, but matte and slag are transferred via covered and hooded launders. For these reasons the conditions inside a plant can be kept clean and hygiene.

## **Intellectual Property Rights**

Outokumpu Technology possesses all the intellectual property rights of Outokumpu Nickel Process covering both the smelter and refinery areas. To successfully transfer the knowledge to a client Outokumpu Technology uses a specific Technology Transfer system, which is based on a good collaboration with the parties and its main advantages are shorter project implementation time, cost savings, share of responsibilities and risk and wide guarantees. The transfer includes the total technology including basic engineering, training, supply of the technology related equipment and supervision for the construction and commissioning. Only in this way the transfer of the existing know-how is secured, a tight implementation time schedule is met and Outokumpu Technology can provide as a technology supplier the performance guarantees for the process as well as for the equipment. All the technology elements are essential to make the technology transfer successful.

## **CONCLUSIONS**

The pyrometallurgical methods dominate the primary step of nickel processing. Outokumpu's nickel flash smelting technology processes about half of the sulphidic concentrate. Refining technology has been developed simultaneously with smelting technology to efficiently process sulphidic concentrate to sellable nickel and other metal products.

The Outokumpu nickel flash smelting and refinery technologies have been in operation for 45 years. During that time the processes and equipment have been developed and a lot of experience and know how have been accumulated. Nowadays technology and process options for various types of sulphide concentrates and nickel mattes are available to fulfill the raw material and product requirements. At the same time the plants using the Outokumpu technology have successfully conformed to the conditions having strong economical and environmental pressures.

The main features of Outokumpu's Nickel Process are:

- High recovery of nickel and especially cobalt and PGM's is improved by elimination of unnecessary molten material circulation by elimination of the converting step in the smelter
- High sulphur fixation from continuous gas flow, i.e. minimum emissions to environment and working atmosphere
- Use of efficient atmospheric and pressure leaching technology as well as use of selective VSF solvent extraction technology
- Use of low cost LTP process for reduction of nickel.

These features of the Outokumpu's nickel smelting and refining technology leads to a possibility to optimise the process concept and operation mode and a flexibility to

treat a wide range of raw material. The result is a low investment and operating cost of smelter, acid plant and refinery.

Outokumpu Technology possesses all the intellectual property rights of Outokumpu Nickel Process covering both the smelter and refinery areas. The technology is transferred to the client by a Technology Transfer system, which is based on a good collaboration and which guarantees a transfer of existing know-how and secures an efficient start of the operation.

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